LA GRANDE ALLIANCE

SOCIÉTÉ DE DÉVELOPPEMENT CRIE
Respect · Collaboration · Puissance

VOLUME 6 - ANNEXE

SECTION 6.15 – Phase 1 de l'étude LGA sur l'électrificationdes chemins de fer

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Vision Eeyou Istchee
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Avec sous-consultant KPMG

Transit
Rolling Stock
Intercity & Heavy Rail

PRELIMINARY REPORT

GRANDE ALLIANCE

Full Electrification Study

Document Reference: LGA-1-BD-T-REL-RT-0001_00

CREE DEVELOPMENT CORPORATION
Respect · Collaboration · Strength

SYSTRA CANADA

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Document
IDENTIFICATION

GRANDE ALLIANCE

Full Electrification Study

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LGA-1-BD-T-REL-RT-0001_00

Table *of* Contents

List *of* Tables

List *of* Figures

1. PURPOSE OF THE STUDY

The purpose of this study is to define all the necessary information and to confirm the assumptions which will be used during the next phases dealing with the Conception design of the Electrification subsystem.

This study is also defining the interfaces and the scope of works of the Electrification subsystem on which the CPEX will be estimated.

Table 1-1: Acronyms and abbreviations

Abbreviation	Meaning
AC	Alternative Current
BEC	Burried Earthing Cable
EN	European Norm
HQ	Hydro-Québec
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
ITC	Integral Transversal Connection
OCS	Overhead Catenary System
OEC	Overhead Earthing Cable
TC	Track Circuit
TPSS	Traction Power Supply System

2. STANDARDS & REFERENCES

For any topic related to the Power supply, CSA/IEEE/UIC will be priorly used. The EN or any other European standard will be applied if and only for specificities of railway technology/environment as this discipline has been explored for decades in Europe which is not the case in North America yet.

3. RAILWAY ELECTRIFICATION

A railway electrification system is the set of means used to supply trains with electrical energy (electric locomotive or electric multiple unit). The trains are powered by medium-voltage alternating current or low-voltage direct current. The power supply passes through a third rail or a catenary and the current return is through the track rails or a dedicated fourth rail.

Early electrical systems used relatively low DC voltages. The electric motors were supplied direct from the overhead contact system or by 3rd rail and controlled by a combination of resistors and contactors which connected the motors in parallel or in series.

Common voltages are 600 Vdc and 750 Vdc for tramways supplied by Overhead Contact System, trolleys and 1,500 Vdc / 3,000 Vdc for metro and urban lines supplied by Overhead Contact System and/or 3rd rail.
Concerning the main lines (intercity and high-speed lines) dedicated for covering high distances, the common voltage is 25kV ac supplied by Overhead Contact system.

A catenary is a set of messenger cables and conductive wires intended to supply electrical means of transport with current collection by a pantograph. The messenger cables are made of bronze or aluminium-steel, while the conducting wires are made of 98% pure copper, or copper alloyed with tin or magnesium.

The railway electrification has been the first alternative solution to the locomotives fed by fossil material (coal, diesel,…) and tested for the first in the early 1800's.
This is the most reliable and experienced solution available on the market at date for decarboning railway lines.

The Grande Alliance project is focusing on 2 main lines covering long-distances in a geographical zone where the HQ network is not easily accessible or even existing.
That is why we will considerer exclusively the 25kVac electrification system as explained previously.

The 2*25 kVca electrification system is relying on two subsystems :

- The Overhead Catenary System (OCS)
- The Traction Power Supply System (TPSS)

These two systems will be detailed in the following chapters.

Find here below a schematic illustrating the global architecture of the electrification network from the National Grid to the Train.

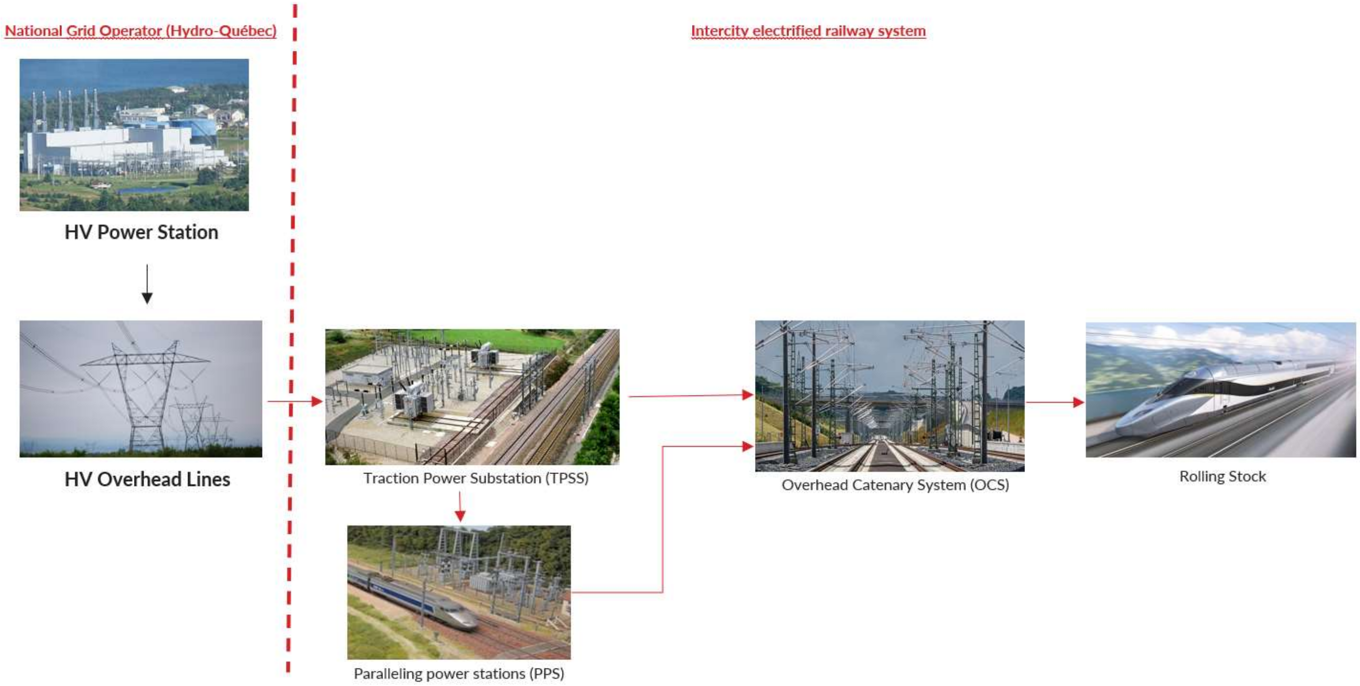


Figure 3-1: Electrification architecture of a railway line

The substation transforms the power from the high-voltage network to 25kVca to supply the catenary. An overhead and/or underground power cables, called feeder which is in opposite phase to the catenary and also at a potential of 25 kV in relation to the rail. The potential difference between the catenary and the feeder is 50 kV.

At regular intervals, an autotransformer connects the rail, the negative feeder and the catenary to supply the train with 25 kV.

The result of this assembly is that the electrical power is then transported over a large part of the route-between the substation and the autotransformer - under a voltage of 50 kV (between the feeder and the catenary), while the autotransformer delivers power to the train at 25 kV (between the catenary and the rail).

In addition, the current feeding the train comes from the two autotransformers which surround it (in front and behind it), lowering the current in a section of catenary

This type of electrification has many advantages:

- Number of substations very limited (spacing around 80 km);
- Voltage drop annihilated;
- EMC and stray current impacts very limited;
- Capacity for delivering a high level of electrical power generated by the train frequency and/or the commercial high-speed.

This electrification is perfectly adapted for railways with long-distance travels or with a high-frequency traffic

4. OVERHEAD CATENARY SYSTEM (OCS)

4.1 GENERAL DESCRIPTION

4.1.1 OCS Structure

The type of OCS planned to be developed for the project shall be compliant with the maximal commercial speed defined by the Client for this project.

In our study, we assume that the line shall be designed for a maximal commercial speed of 100 km/h.

Based on that, the OCS system will be made of:

- A contact wire (Copper or Copper Alloy) with a section of 107 mm^2 or 150 mm^2, wire which shall be compliant with the EN50149. The contact wire will be auto-tensioned through tensioning devices at maximal mechanical force of 26 kN, working on the temperature range applicable for the full corridor of the project.
- A messenger wire (Bronze) with a section of 63 mm^2 or 116 mm^2, wire which shall be compliant with the DIN 48201. The messenger wire will be auto-tensioned through tensioning devices at maximal mechanical force of 20 kN, working on the temperature range applicable for the full corridor of the project.
- An overhead ground wire (Alloy of aluminum and steel) with a section of 93,3 mm^2. The ground wire will be tensioned (4 kN at the project reference*) but will not be auto-tensioned.
- A feeder cable (Alloy of aluminum and steel) with a section of 288 mm^2. The feeder will be tensioned at 9 kN at the reference temperature (to be determined during the project) and will not be auto-tensioned.
- A 25 mm^2 bare copper ground cable. This cable will be buried along each track or alongside one track only, but with grounding connections crossing under the tracks at regular distances to reach the opposite track.
- Droppers made of a Bronze cable.
- Masts.
- Cantilevers.
- Other devices (tensioning devices, insulators, section insulators, etc.).

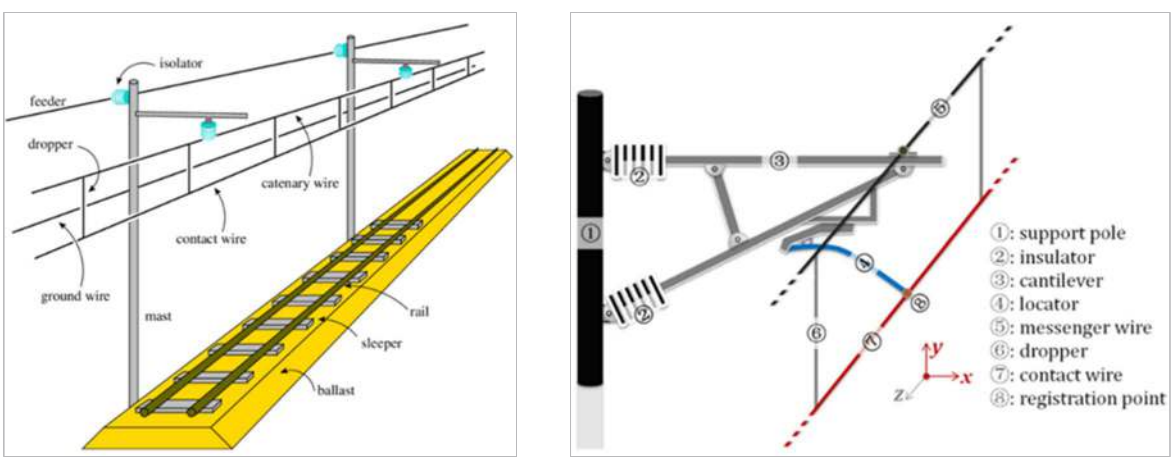


Figure 4-1: 2*25 kVca OCS components

4.2 OCS HIGH-LEVEL CHARACTERISTICS

- Droppers will be defined for each span from the calculation of the intentional deflection.
- The choice of sectioning types and mechanical tensions will be made according to the maximal commercial speed to be reached and the interoperability criteria.
- Exceptionally, the negative feeder may consist of a halogen-free insulated cable with an aluminum core of 240 mm^2 section, configuration used when passing under structures where the free height does not allow the bare feeder to be used.
- The contact plane has an initial deflection equal to $1/2000^{th}$ of the length of the span.
- The catenary is vertical and has no Y suspension.
- The messenger cable is suspended using a suspension clamp.
- The clearance between the messenger and contact wires may vary depending on the type of equipment linked to the configuration (crossover, underbridge, etc.).
- The vertical space required at the mast level is between 0.60 and 2.00 m. The space to be respected at each mast located on the main tracks in nominal conditions shall be between 1.25 and 1.40 m.
- The minimum distance between the messenger and contact wires in the middle of the span shall be equal to 0.375 m for standard droppers and could reach 0.10 m for rigid droppers.
- The nominal height of the contact wire at the registration point is equal to 5.50 m.
- The minimum clearance required under any civil engineering structure as per the CN standard is 7.01 m.
- The length of the spans is limited according to the radii of track curves and the climatic conditions (wind, snow falls and icing, temperatures).

Figure 4-2: OCS 2*25 kVac type for main tracks

4.3 Critical Loads

- Wind speed: 36 m/s (=130 km/h).

This is the "serviceability limit state" (SLS) wind speed. Beyond this wind speed of 130 km/h, the contact wire would come out of the pantograph's sensing range.

- Temperatures: Outdoors: -45°C to +56°C, (if applicable: In tunnel: from -35°C to +65°C)
- Icing: a thickness of 12.5 mm should be considered around the cables, at a temperature of -20°C.

4.3.1 Climatic Loads Combination

The load combinations retained for the project are defined in the following table.

Table 4-1: Table of load combinations to be considered for dimensioning the OCS

	Load case	Conditions	Temperature (°C)	Wind speed (km/h)	Radial Ice/ Frost (mm)
Nominal conditions for Operations	CN1	Wind & Temperature	Tmin= -30 Tmax= 40	130	0
	CN2	Ice & Wind	-20	90	12,5 (ice on all the OCS components excepted the Contact Wire)
	CN3	Only Temperature	Tmin = -45 Tmax = 56	0	0
	Temperature of reference: 15°C. The deflection limits of the wires must respect the limits of Operations.				

Highlights :

- The temperature range considered for case CN1 will be reduced by 15°C for low temperatures and by 15°C for high temperatures, compared to the maximum range (applied for case CN3);
- These combinations do not apply in tunnels, where only the effect of temperatures is taken into account when determining the maximum lengths of laying sections.

4.4 Rolling Stock Characteristics

4.4.1 Pantograph

UIC 608 conditions to be respected

4.4.2 Dynamic and Static Gauge

We have assumed that GA rolling stock would meet the AAR plate M static gauge, applicable to locomotives which is expected to be the most restrictive clearance diagram for the rolling stock that will circulate on the Grande Alliance tracks.

4.4.3 Interoperability

The circulation of railway vehicles on Grande Alliance tracks will be limited to GA rolling stock. At any location where the OCS will cross a CN track, a vertical clearance of 24 ft will be respected between the top or rail and the OCS contact wire or any other structure over the GA tracks.

4.5 OCS TYPES CONSIDERED

4.5.1 OCSType I : Main Line

4.5.1.1 OCS components

La caténaire souple en Voie Courante que nous envisageons serait composée:

- Contact wire under permanent mechanical tension,
- Messenger wire under permanent mechanical tension,
- Feeder,
- An Overhead Earthing Cable,,
- Cantilevers,
- Poles,
- Section insulators,
- Droppers,
- Electrical and mechanical sectioning,
- Anchorings
- Mid-point anchors,
- Connections,
- Switchgears.

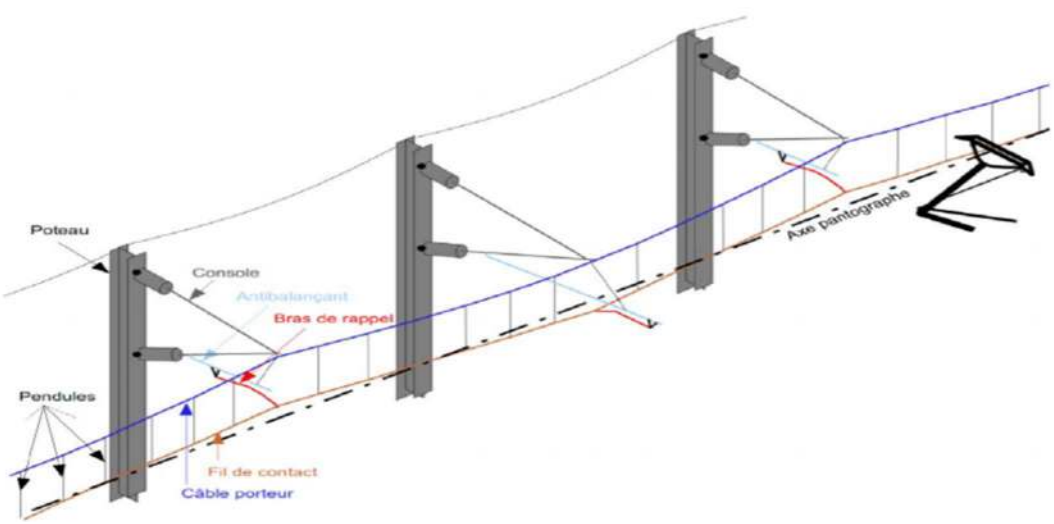


Figure 4-3: OCS Type I illustration

Figure 4-4: Désaxement du fil de contact en courbe

4.5.1.2 Cantilevers

Cantilevers should generally consist of:

- Insulators;
- A bracket tube
- A cantilever tube;
- An anti swing tube;
- A rigid suspension connects the anti-swing tube to the console;
- A steady arm.

For the cantilever and the console tubes, a rotatable fixation with double articulation ensures the connection between the cantilever and the mast.

Each cantilever must be able to rotate freely around a vertical axis so as not to oppose the regularization of the mechanical tension, the creep and the elongation of the conductors.

Cantilever insulators may be made of composite material, ceramic or tempered glass.

The length of the various components parts of the cantilever will rely on:

- The type of equipment;
- Catenary congestion;
- The installation of the support;
- Misalignment of the catenary;
- Equipment dimensions;
- Surcharges allowing subsequent adjustments;
- The slope of the track,
- The way the loads are applied on the structure/component.

4.5.2 Caténaire Type II : Caténaire souple pour Voies Secondaires

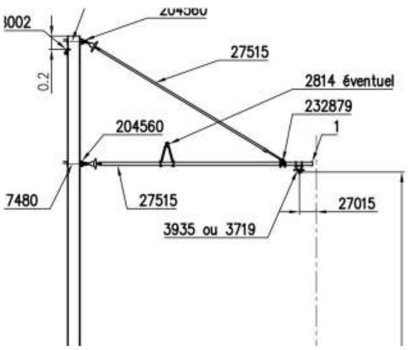
This Catenary is the one to be considered for the railway yards, this one being designed for speeds lower than 50 or 30 km/h.

4.5.2.1 OCS Type II components

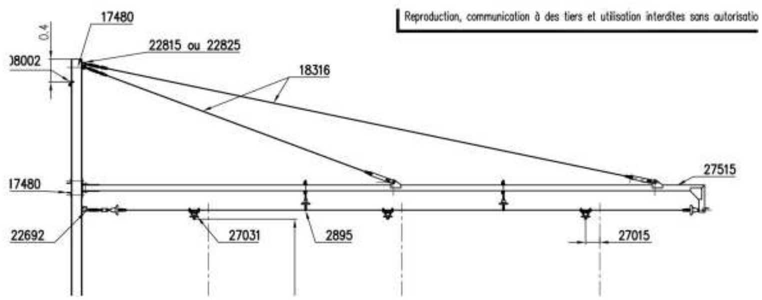
The catenary planned to be implemented will also be a flexible catenary but differs from the Type I catenary due to the low traffic speed in force on such sites (≤30km/h).

Thus this OCS will be made of:

- A non-regulated contact wire (pure copper or copper alloy).
- Foundations.
- Poles,
- Cantilevers.
- Section insulators.
- OCS anchors,
- Electrical connections (feeders, equipotential connections).
- Discharge Intervals,
- Lightning arresters.



Montage Voie Simple



Montage Voies Multiples

Figure 4-5: Illustration d'un faisceau de Centre de Maintenance

5. TRACTION POWER SUPPLY SYSTEM (TPSS)

A 2x25kVac electrified line is supplied with traction energy by a network made up of the following elements:

- Compliance with the requirements relating to the installation of an entire traction energy supply system;
- One or more substations whose power and position are defined on the basis of the characteristics of the line profile, the timetable, operating speeds, rolling stock;
- In-line power stations with one or two autotransformers per station depending on the need and/or the desire for reliability and availability of the installations (principle of redundancy);
- the disconnecting stations at the ends of the supply sector of the substation(s) and between 2 substations in order to isolate the section supplied in the event of an electrical fault or to carry out maintenance operations. Their position depends on those of the substations;
- all equipment and devices along the line such as switches, circuit breakers, disconnectors, neutral section equipment, etc. used for on-line operations and for discrimination in the event of a fault;
- the catenary consisting of a contact wire, a messenger wire and a negative -25 kV feeder exposed at the previous paragraph;
- the rails, the Overhead Earthing Cable (OEC) and the Buried Earthing Cable (BEC), which, connected to earth, represent the main elements of the traction return circuit. This subsystem is the subject of technical booklet No. 10 relating to earthing circuits.

The diagram below illustrates the 2x25kV power supply principle:

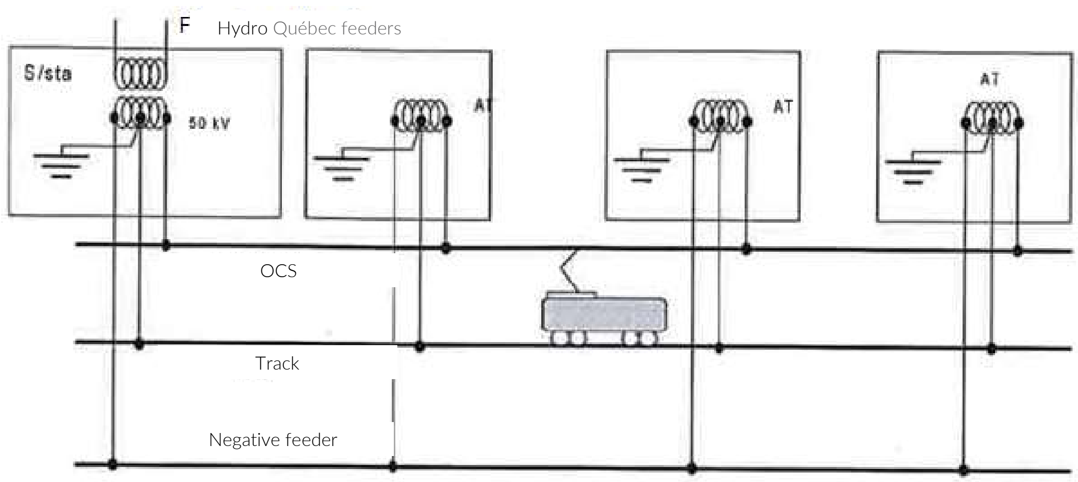


Figure 5-1: 2x25kV power supply principle

The traction power is supplied from the substations to the trains through the OCS, ensured by the operation of the line's circuit breakers, switches and disconnectors.

The traction circuit made of the OCS and the Return Traction Circuit (Rails+ OEC+BEC+ Negative Feeder) are divided into electrical sectors. These main sectors are divided into sub-sectors for maintenance purposes and in the event of incidents. A sector is supplied from traction starters made up of circuit breakers at the substations level, while a subsector is supplied from traction starters made up of switches fed by the in-line power stations (autotransformers).

The train is powered by collecting the current from the catenary through their pantograph. This traction current returns to the substation and to the line substations via the Return Traction Circuit.

The midpoint of the 55 kV transformers is connected to the rails, to the line earth conductors (OEC, BEC) and to the earthing circuit belonging to the substation and in-line power stations.

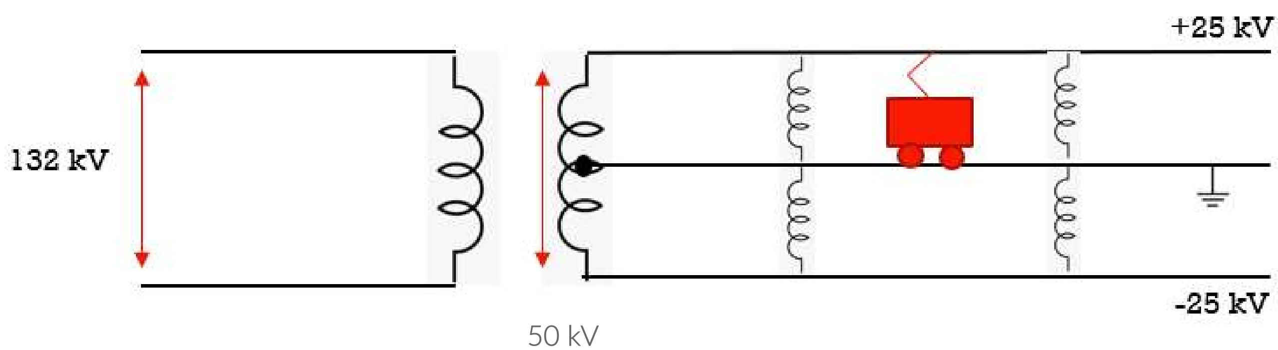


Figure 5-2: Power supply schematic for a 2*25kVca electrification

Circuit breakers, switches and disconnectors are controlled and operated remotely from the PCC. However, this equipment can be manually controlled locally when necessary.

5.1 SUBSTATIONS

The substation is the connection point of the traction supply system to the national electricity transmission and distribution network.

The substation facilities should include the following sections:

- An HT slice ensuring the interface between the HQ and the HTB distribution in the substation to be created;
- A transformation section made up of at least three HV / HV traction transformers producing 2 x 25 Kv;
- A traction energy distribution section supplying the catenary with 2 x 25 kV. The connection between the substation and the catenary is made via a catenary gantry;
- An auxiliary LV section transforming the MV or 25 kV into 230 V and supplying the independent sources and the auxiliaries of the substations;
- A control/command section providing:
  - Local management, supervision and operation of equipment;
  - The interface with the PCC for remote control;
  - Protection.

The block diagram below represents the functional structure of the substation:

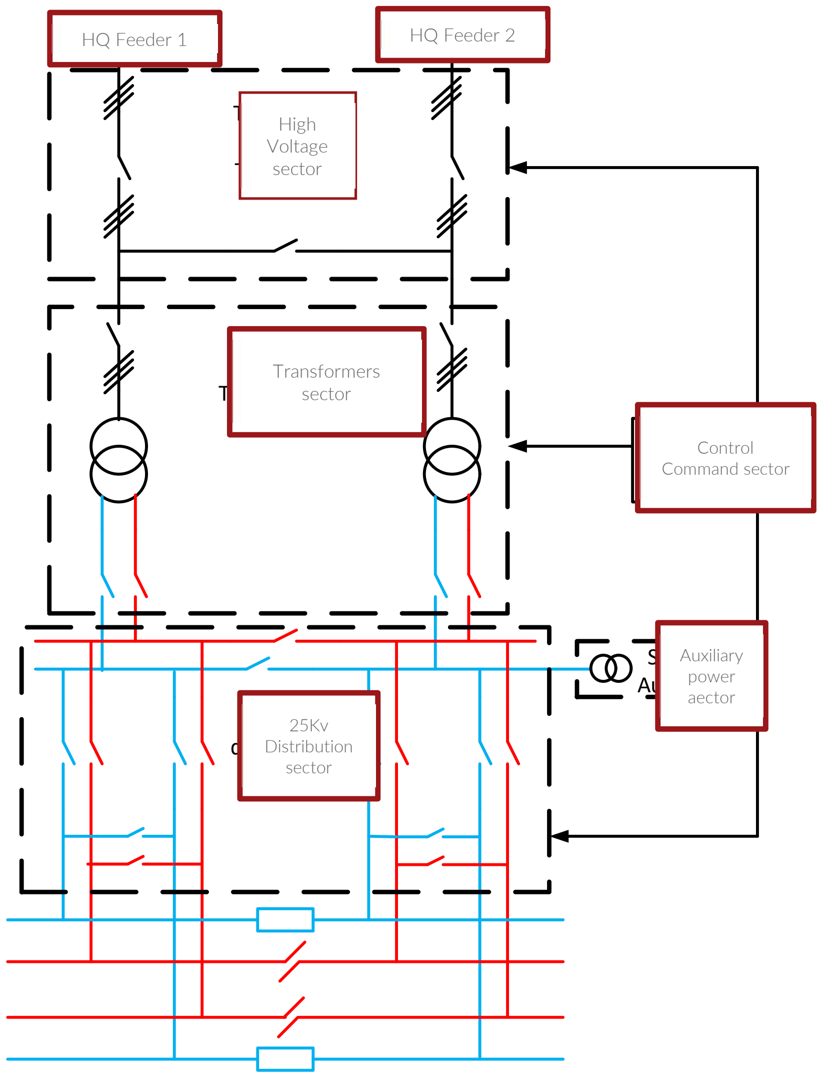


Figure 5-3: Typical Single line diagram of a Substation

Figure 5-4: Picture of a 2*25kVca substation

Figure 5-5: Picture of High-Voltage installations inside a 2*25kVca substation

Figure 5-6: Picture of HV/MV Transformers inside a 2*25kVca substation

5.2 In-Line Power Stations

The In-line power stations located all along the railway line are responsible for paralleling the OCS for reducing the voltage drops. Depending on whether they are paralleling, disconnecting and paralleling power stations or SEI/CAI power, their role is to provide:

- Paralleling the OCS (parallel station with Autotransformers);
- Track paralleling and sectioning allowing two sectors supplied by different sources to be separated (sectioning and paralleling power station);
- Sub-sectioning allowing the division of catenary sectors into elementary sections (SEI/CAI power station),

Depending on their role, paralleling power stations with autotransformers must at least include the following sub-assemblies:

- An autotransformer section comprising two autotransformers (including one backup) and the equipment necessary to perform the functions requested;
- Distribution station including the paralleling switches and the equipment necessary to perform the functions requested;
- Auxiliary services responsible for the distribution of AC and DC power supplies;
- Command and protection control (local SCADA).

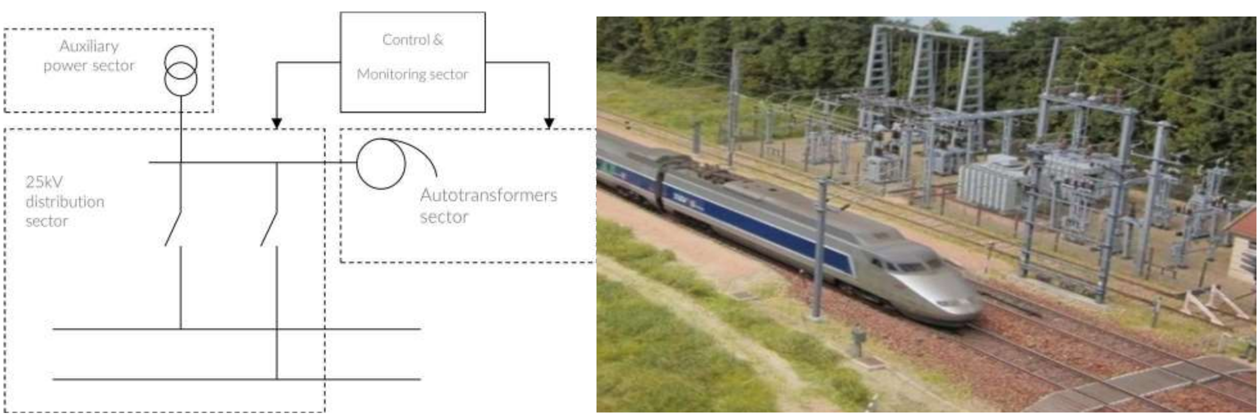


Figure 5-5: Functional layout + photo of a paralleling power station

These autotransformer power stations will be located near the railway platform inside an enclosure to which access is reserved for authorized persons according to the local standards in force.

6. ELECTROMAGNETIC COMPATIBILITY (EMC)

The objective of the EMC design and installation rules is to maintain the level of EMC of individual equipment, qualified in immunity and emission, when they are installed and interfaced in the railway system. To do this, the following topics are taken into account:

- Arrangement of equipment;
- Reduction of conductor loop surfaces in wiring;
- Reduction of grounding impedance;
- Ground mesh and equipotentiality of electrical ground and protective earth networks with minimum impedance;
- Appropriate cable routing design:
  - Minimize installed cable loop surfaces;
  - Shielding, cable screening;
  - Design of adapted cable routes;
  - Apply the correct cable segregation.
- Protect equipment interfaces by:
  - Filtering and protection against electrical transients at the interfaces;
  - Minimize ground impedance;
  - Properly segregate the circuits.

EMC requirements should take precedence over aesthetic or ease of installation considerations, but safety aspects take precedence over any EMC considerations.

ANNEXE

Table 6-1: Standards and references

Standard	Designation
SAFETY IN RELATION WITH ELECTRICAL ENVIRONMENT	
IEC 60364-4	Low-Voltage Electrical Installations - Part 4-41: Protection for Safety - Protection Against Electric Shock
IEC 60445	Basic and safety principles for man-machine interface, marking and identification - Identification of equipment terminals, conductor terminations and conductors
CSA Z462:21	Workplace Electrical Safety – Workshop
UTE C 18-510	Operations on electrical networks and installations in an electrical environment – Electrical risk prevention
UTE C 18-531	Electrical safety requirements for personal exposed to electrical risk during no-electrical work activities and during simple electrical work activities
HIGH VOLTAGE	
HQ F22.01	Medium and High Voltages measuring
HQ E21.12	Red Book
IEC61936 series	Power installations exceeding 1 kV AC
IEC 60044 series	Instrument transformers
IEC 60060 series	High voltage test techniques
IEC 60071 series	Insulation coordination
IEC 60076 series	Power transformers
EN 60214-1	Tap changers – Part 1: Performance requirements and test methods
IEC 60228 series	Conductors of insulated cables
IEC 60255 series	Measuring relays and protection equipment
IEC 60270	High-voltage test techniques - Partial discharge measurements
IEC 60287 series	Electric cables - Calculation of the current rating
IEC 60672 series	Ceramic and glass insulating materials
IEC 60721-3-4	Classification of environmental conditions - Part 3-4: Classification of groups of environmental parameters and their severities - Stationary use at non-weather protected locations

Standard	Designation
IEC 60871 series	Shunt capacitors for a.c. power systems having a rated voltage above 1,000 V
IEC 61869 series	Instrument Transformers
IEC 62271 aeries	High-voltage switchgear and control gear
NF C 13-100	Consumer substations installed inside a building and fed by HV Public distribution system (up to 33 kV)
NF C 13-200	Cable standard for Current Carrying Capacity & Cable Sizing for High Voltage Power Cables
NF C 13 205	High voltage installations: Determination of cross-sectional area of conductors and selection of protective devices
EMC (ELECTROMAGNETIC COMPATIBILITY)	
CAN/CSA-B72	Installation standard for lightning protection
CSA 22.3 No 3-98	Electrical Coordination
CSA 22.3 No 6-13	Principles and practices of electrical coordination between pipelines and electric supply lines
IEC 60950-1	Information Technology Equipment. Safety. General Requirements
IEC 61000-4-1	Electromagnetic Compatibility (EMC). Testing and Measurement Techniques.
IEC 61000-6-2	Electromagnetic Compatibility (EMC) - Part 6-2: Generic Standards - Immunity Standard for Industrial Environments
IEC 61000-5-1	Electromagnetic compatibility (EMC). Part 5 : installation and mitigation guidelines. Section 1: general considerations. Basic EMC publication.
IEC 61000-5-2	Electromagnetic compatibility (EMC). Part 5 : installation and mitigation guidelines. Section 2: earthing and cabling.
IEC 61000-6-1	Electromagnetic compatibility (EMC) - Part 6-1 : generic standards - Immunity standard for residential, commercial and light-industrial environments.
IEC 61000-6-4	Electromagnetic Compatibility (EMC) - Part 6-4: Generic Standards - Emission Standard For Industrial Environments
IEC 61000-3-7	Electromagnetic Compatibility (EMC) - Part 3-7: Limits - Assessment Of Emission Limits For The Connection Of Fluctuating Installations To MV, HV And EHV Power Systems
ICNIRP	Guidelines on limits of exposure to static magnetic fields, International Commission on Non-Ionizing Radiation Protection
ICNIRP	Guidelines for limiting exposure to time-varying electric and magnetic fields (1 Hz – 100 kHz), International Commission on Non-Ionizing Radiation Protection
EN 50121 series	Railway applications - Electromagnetic compatibility

Standard	Designation
EN 55011	Industrial, scientific and medical equipment - Radio-frequency disturbance characteristics - Limits and methods of measurement
EN 55022	Information technology equipment - Radio disturbance characteristics - Limits and methods of measurement
EN 55024	Information technology equipment - Immunity characteristics - Limits and methods of measurement
EN 61800-3	Adjustable speed electrical power drive systems – Part 3: EMC requirements and specific test methods
EN 62040-2	Uninterruptible power systems (UPS) - Part 2: electromagnetic compatibility (EMC) requirements
EN 50173-1	Information technology - Generic cabling systems - Part 1: general requirements
EN 50238-1	Railway applications - Compatibility between rolling stock and train detection systems – Part 1: general
EN 50238-2	Railway applications. Compatibility between rolling stock and train detection systems – Compatibility with track circuits
EARTHING/BOUNDING/GROUNDING	
CSA C22.1-15	Canadian code of electricity, Part 1: Safety standards related to electrical installations
CAN/CSA C22.3-4	Control of Electrochemical Corrosion of Underground Metallic Structures
IEC 60364-4-41	Low-voltage electrical installations – Part 4-41: Protection for safety – Protection against electric shock
IEC 60364-4-44	Low-voltage electrical installations - Part 4-44: Protection for safety - Protection against voltage disturbances and electromagnetic disturbances
IEC 60364-5-54	Low-voltage electrical installations – Part 5-54: Selection and erection of electrical equipment – Earthing arrangements and protective conductors
IEC 62128-1	Railway applications Fixed installations Part 1: Protective provisions relating to electrical safety and earthing
IEEE 80-2000	Guide for Safety in AC Substation Grounding
EN 50122-1	Railway applications - Fixed installations - Electrical safety, earthing and the return circuit - Part 1: Protective provisions against electric shock
EN 50124-1	Railway applications - Insulation coordination - Part 1: Basic requirements - Clearances and creepage distances for all electrical and electronic equipment
EN 50310	Telecommunications bonding networks for buildings and other structures
EN 50522	Earthing of power installations exceeding 1 kV a.c.

Standard	Designation
EN 60664-1	Insulation coordination for equipment within low-voltage systems - Part 1: Principles, requirements and tests
EN 61140	Protection against electric shock - Common aspects for installation and equipment
LIGHTNING PROTECTION	
CAN/CSA-B72	Installation code for lightning protection systems
Site Web Gvt Canada	Lightning activity in Canadian cities- Canada.ca
IEC 60099 series	Surge arresters
IEC 62305-1	Protection against lightning – Part 1 General principles
IEC 62305-2	Protection against lightning - Part 2: Risk management
IEC 62305-3	Protection against lightning – Part 3: Physical damage to structures and life hazard
IEC 62305-4	Protection against lightning - Part 4: Electrical and electronic systems within structures
NF C 17-100	Protection of structures against lightning Installation of lightning Protective system
NF C 17-102	Protection against lightning - Early streamer emission lightning protection systems
RAILWAY ELECTRIFICATION	
CSA 22-3 No 8 – M93	Railway electrification guidelines
AREMA	Manual for railway engineering
IEC 60850	Railway applications - Supply voltages of traction systems
EN 50119	Railway applications - Fixed installations - Electric traction overhead contact lines
EN 50122 series	Railway applications - Fixed installations - Electrical safety, earthing and the return circuit
EN 50124-1	Railway applications Insulation coordination Part 1: Basic requirements Clearances and creepage distances for all electrical and electronic equipment
EN 50125-2	Railway applications - Environmental conditions for equipment Part 2: Fixed electrical installations
EN 50128	Railway applications – Communication, signalling and processing systems
EN 50149	Railway applications - Fixed installations - Electric traction - Copper and copper alloy grooved contact wires
EN 50152 series	Railway applications - Fixed installations - Particular requirements for a.c. switchgear
EN 50159	Railway applications - Communication, signalling and processing systems - Safety-related communication in transmission systems
EN 50160	Voltage characteristics of electricity supplied by public electricity networks

Standard	Designation
EN 50388	Railway Applications - Power supply and rolling stock - Technical criteria for the coordination between power supply (substation) and rolling stock to achieve interoperability
Technical Specification for Interoperability (abbreviated as TSI)	Technical specification for interoperability (TSI) drawn up for the Traction power subsystem

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